i) differentially compares a first signal and a second signal in a way that is effective to minimize a background magnetic field component and provides resultant output signals;

ii) determines the characteristics of the first magnetic field present in the resultant output signals; and

iii) provides a representation of the first magnetic field;

wherein the representation is useful in diagnostic imaging of the subject.

REMARKS

The amendments to claims 1, 29, 34, 38, 42, 54, 66, and 79, and new claims 84, 85, 87, 88, 90, and 91 are supported at least at page 8, 2nd and 4th paragraphs; page 21, last paragraph; page 23, 3rd paragraph; Examples 1 and 3; and Fig. 6.

The amendments to claims 4, 46, 56, and 69 are supported at least at page 6, 6th paragraph; the paragraph bridging pages 23 and 24; and Example 3, page 31, last paragraph (the dashed line in Fig. 8 referred to in the text gives a sensitivity for a single channel atomic magnetometer of 10 $fT/Hz^{1/2}$).

New claims 83, 86, 89, and 92 are supported at least at page 23, 3rd paragraph, and Examples 2 and 3.

New claims 93 and 94 are supported generally throughout the specification and claims 1-82 as originally filed.

The amendment to claim 42 (in paragraph a)), is supported at least in claim 42 as originally filed, at pages 24-25 including Fig. 5 referred to there, and Examples 6 and 8 including Fig. 10 referred to therein. Applicant believes that the scope of paragraph a) in claim 42 as amended is unchanged from that of paragraph a) as originally filed.

The amendments to claims 30, 39, 62, 65, 67, and 76 are offered to clarify the recitations of the claims and correct editorial errors.

No new matter is introduced in these amendments.

ARGUMENT

A. Summary of the Invention

In a first aspect, the present invention provides a high sensitivity atomic magnetometer that includes

a) a sensing cell containing a mixture comprising an alkali metal vapor and a buffer gas, wherein the sensing cell is exposed to a background magnetic field lower than a first predetermined value;

b) means for increasing the magnetic polarization of the alkali metal vapor thereby increasing the sensitivity of the alkali metal vapor to a low intensity magnetic field;

c) magnetizing means for imposing a magnetic field on a volume of space comprising the sensing cell;

d) means for probing the magnetic polarization of the alkali metal vapor, the probing means providing an output from the alkali metal vapor, the output comprising characteristics related to the low intensity magnetic field; and

e) measuring means wherein the measuring means receives the output, determines the characteristics of the low intensity magnetic field, and provides a representation of the low intensity magnetic field, wherein the measuring means comprises a plurality of output detecting means.

In an additional aspect, the present invention provides a high sensitivity atomic magnetometer that generates a representation of a first magnetic field originating within a sample volume, the magnetometer including

a) a sensing cell sensitive to low intensity magnetic fields comprising an alkali metal vapor and a buffer gas, the sensing cell being adjacent to a sample volume including a component generating a first magnetic field, wherein the sensing cell is exposed to

i) the first magnetic field; and

ii) a background magnetic field lower than a first predetermined value;

b) means for increasing the magnetic polarization of the alkali metal vapor, wherein the magnetic polarization of the alkali metal vapor includes a contribution from the first magnetic field;

c) magnetizing means for imposing a second magnetic field on a volume of space comprising the sensing cell;

d) means for probing the magnetic polarization of the alkali metal vapor, the probing means providing an output from the vapor comprising characteristics related to the first magnetic field; and

e) measuring means for receiving the output, determining the characteristics of the first magnetic field, and providing a representation of the first magnetic field, wherein the measuring means comprises a plurality of output detecting means.

In yet an additional aspect the invention provides a high sensitivity diagnostic imaging atomic magnetometer comprising

a) a sensing cell sensitive to low intensity magnetic fields, the sensing cell comprising an alkali metal vapor and a buffer gas, the sensing cell being adjacent to a sample volume for containing at least a portion of a subject that generates a first magnetic field, wherein the sensing cell is exposed to

i) the first magnetic field; and

ii) a background magnetic field;

b) a first radiation generating means that generates a first beam of radiation illuminating the alkali metal vapor, the first beam being effective to increase the magnetic polarization of the alkali metal vapor, wherein the magnetic polarization of the alkali metal vapor includes a contribution from the first magnetic field;

c) magnetizing means for imposing a second magnetic field on a volume of space comprising the sensing cell;

e) one or more second radiation generating means that generates one or more second beams of radiation traversing the alkali metal vapor for probing the magnetic polarization of the alkali metal vapor, the one or more second radiation beams providing one or more second output beams of radiation after they traverse the vapor, the second output beams comprising characteristics related to the first magnetic field;

f) a plurality of output detecting means that detect the second output beams and provide a plurality of signals comprising characteristics related to the first magnetic field;

g) a computational module comprising a plurality of signal processing means for

i) receiving the plurality of signals;

ii) differentially comparing a first signal and a second signal in a way that is effective to minimize a background magnetic field component in the signals thereby providing resultant output signals;

iii) determining the characteristics of the first magnetic field present in the resultant output signals;

iv) and providing a representation of the first magnetic field;

wherein the representation is useful in diagnostic imaging of the subject.

In further aspects, the invention provides a method for providing a representation of a low intensity magnetic field detected by a sensing cell that has high sensitivity to a magnetic field, a method for providing a representation of a first magnetic field originating within a sample volume, and a method of conducting diagnostic imaging on a subject. These methods employ apparatuses such as a high sensitivity atomic magnetometer of the invention, or a high sensitivity atomic magnetometer, or a high sensitivity diagnostic imaging atomic magnetometer that generate a representation of a first magnetic field originating within a sample volume provided by the present invention.

Various embodiments of the atomic magnetometers described in the specification include, and various embodiments of the methods described in the specification employ magnetometers that include, measuring means including a plurality of output detecting means that provide a plurality of signals containing characteristics related to the low intensity magnetic field, and a plurality of signal processing means for receiving the plurality of signals and providing the representation. In further embodiments of the magnetometers and methods, a first output detecting means detects radiation traversing a first region of the alkali metal vapor and a second output detecting means detects radiation traversing a second region of the alkali metal vapor, wherein the first and second regions are different. In yet additional embodiments of the magnetometers and methods of the invention, the measuring means include computational means for differentially comparing a first signal and a second signal in a way that is effective to minimize a contribution of the background magnetic field.

B. Summary of Allred et al.

Allred et al. describe a K (potassium) magnetometer haaving only a single photodiode detector (see the bottom center of Fig. 1). The magnetometer is described generally on page

130801-1, col. 2 and 130801-2, col. 1, and a schematic representation is shown in Fig. 1 on page 130801-2. It is to be noted that direct measurements of the signal-to-noise ratio give a magnetometer sensitivity of 10 femtotesla $(Hz)^{-1/2}$ (see Abstract and page 130801-3, col. 1), which Applicants submit is a relatively poor magnetometer sensitivity.

C. The present invention is not anticipated by Allred et al.

The present invention, as disclosed in Section III.A, above, claims an atomic magnetometer that includes a measuring means that includes a plurality of output detecting means. Allred et al. fails to disclose a plurality of output detecting means, and fails to disclose a plurality of output detecting means providing a plurality of signals. In addition Allred et al. fails to disclose a first output detecting means that detects radiation traversing a first region of the alkali metal vapor and a second output detecting means that detects radiation traversing a second region of the alkali metal vapor, wherein the first and second regions are different. Still further, Allred et al. fails to disclose measuring means that include computational means for differentially comparing a first signal and a second signal in a way that is effective to minimize a contribution of the background magnetic field. In addition, Allred et al. fails to disclose a measured magnetometer limit of detectability less than 10 femtotesla $(Hz)^{-1/2}$.

For these reasons Applicants respectfully submit that claims 1-94 of the present invention are not anticipated by Allred et al. Since all rejections have been overcome Applicants respectfully request that claims 1-94 be found allowable at this time.

IV. Notification of Recordation of Assignment.

In response to paragraph 3 of the Office Action, Applicants are submitting a copy of the Notice of Recordation of Assignment for this application for entry into the file.

Respectfully submitted,

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39,096
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